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Tests on price linkage between the U.S. and Japanese gold and silver futures markets

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Abstract

We tested the price linkage, the law of one price (LOP) condition, and the causality of the price linkage between the U.S. and Japanese gold and silver futures markets with consideration of structural breaks in the price series. The LOP condition did not hold for both the gold and silver markets when structural breaks were not considered but it sustained in some periods when it was tested for the break periods. We found from the causality test that the price linkage between the U.S. and Japanese gold and silver futures markets were led by the U.S. market.

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1. Introduction

Whether international linkage exists for the gold and silver futures markets is an important issue. This is because gold and silver have been historically considered as asset to hedge against economic uncertainty. International linkage among futures markets has been studied for agricultural commodities such as wheat (Goodwin, 1992) and soybean meal (Yang et al., 2000) but there are not many studies examining this for gold and silver futures markets. To fill this gap we analyze the price relationship between the U.S. and Japanese gold and silver futures markets. The study identifies if the U.S. and Japanese gold and silver futures markets move together in the long-run, examines the law of one price (LOP) condition, and tests the causality of the long-run relationships. We use the 2001-2010 daily data, which includes the global financial crisis of 2008. Hence, we test the price linkage when effects of structural breaks in the price series are considered as well.

The results of the study will reveal whether international linkage exists for the gold and silver futures markets, the degree of the linkage, and the cause of the linkage. Therefore, the study will be useful when constructing effective global risk management strategies for investors and industries involved in the gold and silver markets.

In the next section the methods used in the study are explained. The third section describes the data. Results are shown in the fourth section. Section five provides the conclusion of the study.

2. Methods

The long-run price linkage, the LOP condition, and the causality of the long-run relationship between the U.S. and Japanese gold and silver futures prices are tested under the Johansen cointegration method (Johansen and Juselius, 1990). Cointegration requires all price series to be integrated of the same order so initially unit root tests are performed on all price series used in the study. We use the augmented Dickey-Fuller (1979), Phillips-Perron (1988), and Kwiatkowski-Phillips-Schmidt-Shin (1992) unit root tests for this purpose. If we find that the price series are integrated of the same order from the unit root tests, we perform the Johansen test between the U.S. and Japanese gold and silver futures prices. The Johansen test is performed using the following vector error correction model:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{q-1} \Gamma_i \Delta Y_{t-i} + \mu + \varepsilon_t \qquad (1)$$

where Y_t is the $n \times 1$ vector $(Y_{1t}, Y_{2t}, \cdots, Y_{nt})'$ of futures prices, q is the order of the vector autoregressive process, $\Pi = -I + \sum_{i=1}^{q} \Pi_i$ and $\Gamma_i = -\sum_{j=i+1}^{q} \Pi_j$ where Π_i

and Π_j are the $n \times n$ matrix of parameters, μ is a constant, and ε_t is a normally distributed n-dimensional white noise process. When cointegration relationship is found between the price series it is known that the Π matrix in equation (1) can be decomposed as $\Pi = \alpha\beta'$ (Johansen, 1991).

The LOP condition and the causality of the long-run relationship are tested by imposing restrictions on the Π matrix. Thus it is necessary that a cointegration relationship holds between the U.S. and Japanese gold and silver futures prices. The LOP condition is tested under the following equation:

$$P_t^{US} = a + bP_t^{JP} + e_{t,} \quad (2)$$

where P_t^{US} and P_t^{JP} are the prices of the U.S. and Japanese gold and silver futures contracts at time *t*, a is a constant, b is a coefficient, and e_t is the error term.[1] In this study we tested whether $b = 1$ holds in equation (2), which is called the weak version of the LOP test (see Asche et al, 2004).[2] This test is performed by putting a restriction on the β part of the Π matrix. The causality test is performed by incorporating a restriction to the α part of the Π matrix. The hypothesis tested in the causality test is that the U.S. price leads the gold or silver futures prices to reach the long-run relationship.

The Bai-Perron test (Bai and Perron, 1998) is used to identify whether structural breaks exists in the price relationship between the U.S. and Japanese gold and silver futures prices. This test is useful for identifying multiple structural breaks in the price series when breaks are unknown. First the test performs the un-weighted and weighted maximum tests to find out whether at least one break exists in the price series. Once the existence of one break is confirmed by these double maximum tests, the Bai-Perron test goes further to statistically identify the appropriate number of breaks by the $supF(l+1|l)$ test. The $supF(l+1|l)$ test tests the null hypothesis of having l breaks in the price series against the alternative hypothesis of having $l+1$ breaks. The price ratio between the U.S. and Japanese futures prices for gold and silver (P_t^{US}/P_t^{JP}) is used for the Bai-Perron test.[3]

After the breaks are determined by the Bai-Perron test the whole gold and silver price series are separated into break periods using the break dates identified by the Bai-Perron test. Then the same unit root tests, Johansen cointegration test, LOP test, and causality tests are tested for each break period to see if the price relationship between

[1] The prices of Japanese gold and silver futures contracts are converted into U.S. dollars.
[2] In the strong version of the LOP it also requires $a = 0$ to hold in equation (2) (see Asche et al., 2004).
[3] We followed Kristofersson and Anderson (2006) of using the price ratio to identify the structural breaks in the price relationship between the two price series. In the Bai-Perron test we set the maximum number of breaks to five and the trimming value to 0.15 (see Bai and Perron (1998) for details).

the U.S. and Japanese gold and silver futures markets changed before and after the break dates.

3. Data

For the U.S. gold and silver futures prices the daily continuous futures prices of Commodity Exchange Inc. (COMEX) gold and silver futures contracts are used in the study. The daily continuous price data for these COMEX futures prices are obtained from the EODData, LLC.[4] The Japanese gold and silver futures prices are taken from the Tokyo Commodity Exchange (TOCOM). The furthest contracts are the most active contracts at the TOCOM market so the daily continuous TOCOM gold and silver futures prices are created using the prices for the furthest contracts. January 2001 to June 2010 period is covered for the COMEX and TOCOM gold and silver futures prices.

To match the minimum price units, all daily gold and silver futures prices are converted to U.S. dollars per gram. The TOCOM gold and silver prices are converted to U.S. dollars by using the daily currency rate between the U.S. dollars and Japanese yen. The daily currency rate is obtained from the OANDA Corporation.

[4] The futures prices for the most active contracts were used for the continuous price data.

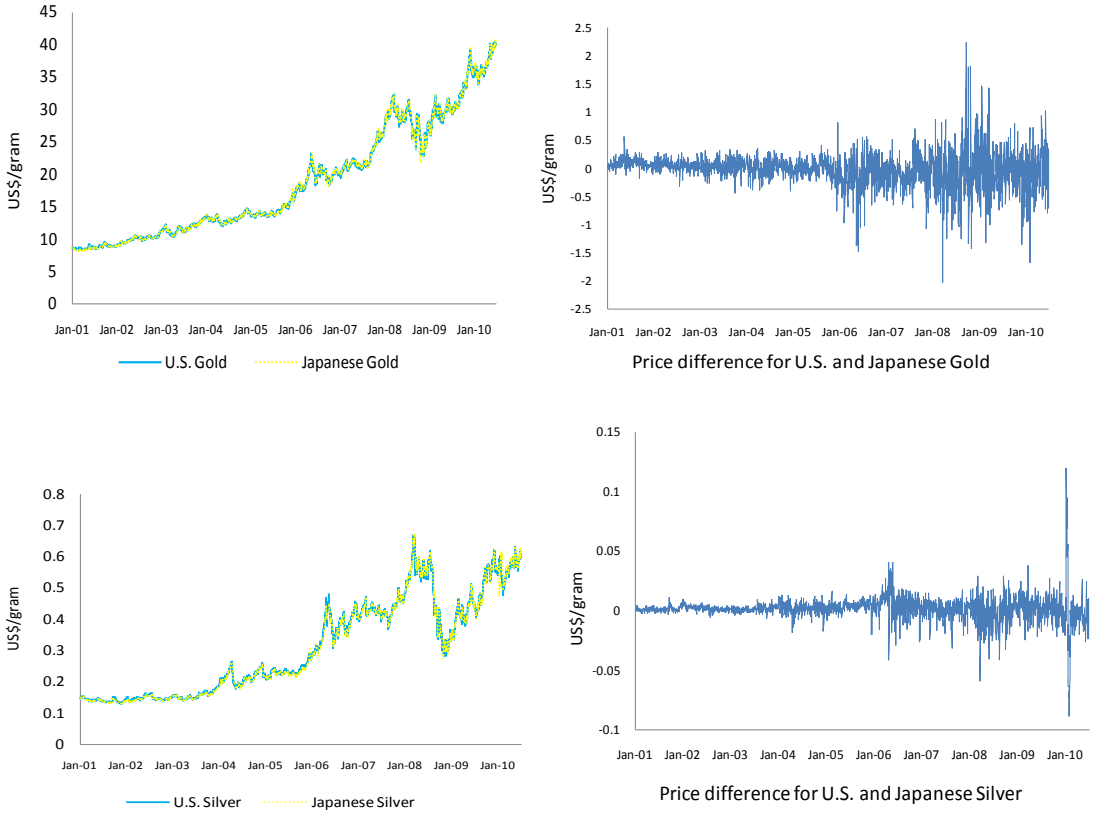

Figure 1: Plots of U.S. and Japanese gold and silver futures prices and their price differences

Figure 1 presents the plots of U.S. and Japanese gold and silver futures prices and the price difference between the U.S. and Japanese prices for gold and silver. In both the gold and silver futures markets the U.S. and Japanese prices seem to move together during the period used in this study so it is likely that the U.S. and Japanese prices will have a cointegration relationship in these markets.

4. Results

Before performing the Johansen test we performed the unit root tests to check if all price series used in the study are integrated of the same order. The unit root tests conducted for the whole test period revealed that all price series are integrated of order one (see Table 1). Hence, we performed the Johansen test between the U.S. and Japanese futures prices for the gold and silver futures markets.

Table 1: Unit root tests

Variable	Log Level			First difference of log level		
	ADF	PP	KPSS	ADF	PP	KPSS
U.S. Gold	-1.978	-2.121	1.025*	-11.454*	-46.632*	0.020
U.S. Silver	-3.252	-3.367	0.324*	-11.197*	-48.093*	0.026
Japanese Gold	-1.965	-2.312	0.996*	-13.096*	-52.365*	0.018
Japanese Silver	-3.021	-3.253	0.327*	-15.931*	-50.583*	0.029

Notes: * denotes significance at 1%. All the unit root tests for the level and first differences include constant and trend. Lag orders for the ADF tests are determined by the AIC and the bandwidth for the PP and KPSS tests are identified by Newey-West method (Newey and West, 1994).

Table 2: Cointegration tests without breaks

Test variables	H_0: rank=r	Trace test	Max test	LR test statistic for the law of one price	Variables	LR test statistic for the causality test
U.S. Gold vs Japanese Gold	r=0	104.80**	104.03**	22.75**	U.S.	1.58
	r<=1	0.77	0.77		Japanese	94.23**
U.S. Silver vs Japanese Silver	r=0	247.25**	246.75**	20.02**	U.S.	0.00
	r<=1	0.50	0.50		Japanese	214.07**

Note: ** represents significance at 5% level.

As seen from Table 2, for both the gold and silver futures markets, the U.S. and Japanese prices have a cointegration relationship and there is a long-run price linkage between the gold and silver futures markets of the two countries. However, for both the gold and silver markets, the LOP condition did not hold between the U.S. and Japanese futures prices. The causality test showed that in both the gold and silver futures markets it is the U.S. price that binds the U.S. and Japanese prices to move together in the long-run.

Table 3: Bai-Perron tests

	Gold	Silver
Test	Statistic	Statistic
UDmax	153.17**	49.84**
WDmax	165.97**	55.73**
sup-F(2|1)	117.73**	12.99**
sup-F(3|2)	20.23**	11.46**
sup-F(4|3)	10.17	2.67

Note: ** denotes significance at 5% level.

The Bai-Perron test revealed that three breaks exists in the January 2001 to June 2010 period covered in this study (see Table 3). Hence this whole period was split into four break periods using the break dates identified by the Bai-Perron tests. The details of the break dates for gold and silver markets are presented in Tables 4 and 5. The same above mentioned unit root tests, the Johansen test, the LOP test, and the causality test are performed on these break periods. Tables 4 and 5 show these results for the gold and silver futures markets.[5]

Table 4: Cointegration tests with breaks for the U.S. and Japanese gold futures markets

Period	Dates	H_0: rank=r	Trace test	Max test	LOP	Variables	Causality test
1	Jan. 4, 2001 - Jun. 3, 2002	r=0	23.96**	23.88**	2.88	U.S.	1.83
		r<=1	0.08	0.08		Japan	15.70**
2	Jun. 4, 2002 - Oct. 7, 2005	r=0	73.86**	73.42**	2.23	U.S.	1.94
		r<=1	0.44	0.44		Japan	71.84**
3	Oct. 11, 2005 - Aug. 14, 2008	r=0	39.77**	37.78**	0.35	U.S.	2.21
		r<=1	2.00	2.00		Japan	35.23**
4	Aug. 15, 2008 - Jun. 30, 2010	r=0	192.00**	191.39**	9.29**	U.S.	0.06
		r<=1	0.62	0.62		Japan	160.00**

Note: ** represents significance at 5% level.

Table 5: Cointegration tests with breaks for the U.S. and Japanese silver futures markets

Period	Dates	H_0: rank=r	Trace test	Max test	LOP	Variables	Causality test
1	Jan. 4, 2001 - Jul. 18, 2002	r=0	20.13**	18.05**	0.96	U.S.	3.17
		r<=1	2.09	2.09		Japan	9.57**
2	Jul. 19, 2002 - May 2, 2005	r=0	209.36**	207.62**	17.70**	U.S.	0.62
		r<=1	1.74	1.74		Japan	188.03**
3	May 6, 2005 - Dec. 13, 2006	r=0	41.74**	41.50**	0.36	U.S.	12.45**
		r<=1	0.24	0.24		Japan	16.18**
4	Dec. 14, 2006 - Jun. 30, 2010	r=0	123.87**	120.84**	13.20**	U.S.	0.02
		r<=1	3.03	3.03		Japan	99.18**

Note: ** represents significance at 5% level.

Tables 4 and 5 reveal that in both the gold and silver futures markets in every period the U.S. and Japanese markets have cointegration relationships. This implies that the price linkage between the two countries for the gold and silver futures markets was not affected by the breaks. However, the results in the tables suggest that the LOP condition and the causality of the cointegration relationship are affected by the structural breaks in the price series. Table 4 shows that the LOP condition holds for the gold market until August 2008 but this condition did not meet in the fourth period. The LOP condition also did not hold for the second and fourth period for the silver market

[5] The results of the unit root tests suggested that in all break periods the price series used in the test periods are integrated of the same order.

(see Table 5). For the silver market, Table 5 shows that the causality of the cointegration relationship between the U.S. and Japanese markets are also affected in the third period. These results imply that although the price relationship between the U.S. and Japanese gold and silver markets sustained even with the effects of structural breaks, the level of arbitrage and the cause of the price relationship between the U.S. and Japanese markets did have an influence from the breaks in the price series.

5. Conclusion

This study tested the price linkage, the law of one price (LOP) condition, and the causality of the price linkage between the U.S. and Japanese gold and silver futures markets with consideration of structural breaks in the price series. We find price linkage do exist between the U.S. and Japanese gold and silver futures markets. This suggests that gold and silver futures markets are interdependent and price information can be shared between the two countries. The LOP condition did not hold for both the gold and silver markets when structural breaks were not considered but it sustained in some periods when tested this condition for the break periods. This implies that for the whole test period arbitrage was not perfect between the U.S. and Japanese market but there were periods where arbitrage was very quick and price information were perfectly shared between the two countries. The causality test revealed that it is the U.S. price that leads the gold and silver futures markets to reach the long-run relationship but this price leadership was also affected for the silver market when tested for the break periods.

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